

# A simplified view of blazars: the very high energy $\gamma$ -ray vision

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## ABSTRACT

We have recently proposed a simplified scenario for blazars in which these sources are classified as flat-spectrum radio quasars or BL Lacs according to the prescriptions of unified schemes, and to a varying combination of Doppler boosted radiation from the jet, emission from the accretion disk, the broad line region, and light from the host galaxy. This scenario has been thoroughly tested through detailed Monte Carlo simulations and reproduces all the main features of existing radio, X-ray, and  $\gamma$ -ray surveys. In this paper we consider the case of very high energy emission ( $E > 100$  GeV) extrapolating from the expectations for the GeV band, which are in full accordance with the *Fermi*-LAT survey results, and make detailed predictions for current and future Cherenkov facilities, including the Cherenkov Telescope Array. Our results imply that  $\gtrsim 100$  new blazars can be detected now at very high energy and up to  $z \sim 1$ , consistently with the very recent MAGIC detection of S4 0218+35 at  $z = 0.944$ .

**Key words:** BL Lacertae objects: general — quasars: general — radiation mechanisms: non-thermal — radio continuum: galaxies — gamma-rays: galaxies

## 1 INTRODUCTION

Blazars are a class of Active Galactic Nuclei (AGN) characterised by distinctive and extreme observational properties, such as large amplitude and rapid variability, superluminal motion, and strong emission over the entire electromagnetic spectrum. Blazars also host a jet, pointing almost directly to the observer, within which relativistic particles moving in a magnetic field radiate by losing their energy (Blandford & Rees 1978; Urry & Padovani 1995), at variance with most AGN whose energy production is mostly through accretion of matter onto a supermassive black hole. The two main blazar sub-classes, namely BL Lacertae objects (BL Lacs) and flat-spectrum radio quasars (FSRQs), differ mostly in their optical spectra, with the latter displaying strong, broad emission lines and the former instead being characterised by optical spectra showing at most weak emission lines, sometimes exhibiting absorption features, and in many cases being completely featureless.

Although blazars represent a small fraction of AGN, the

interest in this type of peculiar and rare sources is growing as they are being found in increasing large numbers in high Galactic latitude surveys performed at microwave and  $\gamma$ -ray energies (Giommi et al. 2009; Ackermann et al. 2011; Planck Collaboration et al. 2011a). Blazars represent also the most abundant extragalactic population at TeV energies<sup>1</sup>. Very recently Padovani & Resconi (2014), on the basis of a joint positional and energetic diagnostic, have even suggested a possible association between BL Lacs and seven neutrino events reported by the IceCube collaboration (Aartsen et al. 2014).

In a recent paper (Giommi et al. 2012a, hereafter Paper I) we proposed a new paradigm, which is based on light dilution, minimal assumptions on the physical properties of the non-thermal jet emission, and unified schemes. These posit that BL Lacs and FSRQs are simply low-excitation (LERGs)/Fanaroff-Riley (FR) I and high-excitation (HERGs)/FR II radio galaxies with their jets forming a small angle with respect to the line of sight. We called this new approach the *blazar simplified view* (BSV).

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By means of detailed Monte Carlo simulations, Paper I showed that the BSV scenario is consistent with the complex observational properties of blazars as we know them from all the surveys carried out so far in the radio and X-ray bands, solving at the same time a number of long-standing issues.

In a subsequent paper (Giommi, Padovani, & Polenta 2013, hereafter Paper II) we extended the Monte Carlo simulations to the  $\gamma$ -ray band (100 MeV – 100 GeV) and found that our results matched very well the observational properties of blazars in the *Fermi*-LAT 2-yr source catalogue (Nolan et al. 2012; Ackermann et al. 2011, hereafter 2LAC) and the *Fermi*-LAT data of a sample of radio selected blazars (Giommi et al. 2012b; Planck Collaboration 2011b).

Arsioli et al. (2014) have recently put together a sample of  $\sim 1,000$  high synchrotron peaked (HSP) blazars, that is objects with the frequency of the synchrotron peak  $\nu_{\text{peak}}^S > 10^{15}$  Hz. This was defined starting from a primary list of infrared (IR) colour-colour selected sources from the ALL-WISE<sup>2</sup> survey, based on data from the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010), and applying further restrictions on IR-radio and IR-X-ray flux ratios. This so-called WISE HSP (1WHSP) sample is currently the largest sample of confirmed and candidate HSP blazars. All these objects are expected to accelerate particles to the highest observed energies and radiate up to the very high energy  $\gamma$ -ray band.

The purpose of this paper is to push into the very high energy (VHE;  $E > 100$  GeV) band of the electromagnetic spectrum by extrapolating our simulations from the lower energy (*Fermi*)  $\gamma$ -ray band and: a) make detailed predictions for current and future Imaging Atmospheric Cherenkov Telescopes (IACTs), including the Cherenkov Telescope Array (CTA); b) compare our predictions with the number of observed bright 1WHSP sources. As in Paper I and II we use a  $\Lambda$ CDM cosmology with  $H_0 = 70$  km s<sup>-1</sup> Mpc<sup>-1</sup>,  $\Omega_m = 0.27$  and  $\Omega_\Lambda = 0.73$  (Komatsu et al. 2011).

## 2 SIMULATIONS

Our goal is to estimate the properties of a VHE flux-limited blazar sample, building upon the simulations presented in Paper I and Paper II, applying the same prescriptions. In Paper II we were mainly interested in distributions, trends, and average values. To make our predictions as robust as possible, in view of the required extrapolations, in this paper we reproduced the absolute numbers in the *Fermi* 2LAC catalogue as well. This required some minimal fine tuning and a very small number of changes to our input parameters, which do not have any impact on our previous results.

Our Monte Carlo simulations construct the radio through  $\gamma$ -ray spectral energy distributions (SEDs) of blazars at different redshifts and are based on various ingredients, which include: the blazar luminosity function and evolution, a distribution of the Lorentz factor of the electrons and of the Doppler factor, a synchrotron inverse

Compton model, an accretion disk component, the host galaxy. A series of  $\gamma$ -ray constraints based on observed distributions estimated using *simultaneous* multi-frequency data are also included: namely, the distribution of Compton dominance, the dependence of the  $\gamma$ -ray spectral index on  $\nu_{\text{peak}}^S$ , and that of the  $\gamma$ -ray flux on radio flux density. Sources are classified as BL Lacs, FSRQs, or radio galaxies based on the optical spectrum, as normally done with real surveys. Readers are referred to Paper I and II for full details.

The SEDs were extrapolated to the VHE band by using our simulated *Fermi* fluxes and spectral indices and assuming a break at  $E = E_{\text{break}}$  and a steepening of the photon spectrum by  $\Delta\Gamma$ . Our default values are  $E_{\text{break}} = 100$  GeV and  $\Delta\Gamma = 1$ . The former is consistent with the SEDs shown in Fig. 8 in Şentürk et al. (2013), while the latter has been derived as follows: we calculated  $\Gamma_{\text{TeV}} - \Gamma_{\text{GeV}}$  for the sources in Tab. 1 and 2 of Şentürk et al. (2013) with  $z \leq 0.1$  to minimise the effect of the extragalactic background light (EBL) absorption. The resulting value is  $\langle \Delta\Gamma \rangle = 1.1$  which, since EBL absorption is important at higher energies even at low redshifts, should be taken as a conservative value. To see how strongly our results depend on this choice we employed also a harder spectrum, that is one with  $E_{\text{break}} = 200$  GeV and  $\Delta\Gamma = 0.5$ . VHE spectra were attenuated using recent estimates of the EBL absorption as a function of redshift (Dominguez et al. 2011).

In the rest of the paper we refer to the two different extrapolations as “soft” and “hard” respectively.

## 3 PREDICTIONS FOR THE VHE BAND

We present the integral number counts as a function of photon flux ( $E \geq 100$  GeV) for our default VHE extrapolation ( $E_{\text{break}} = 100$  GeV and  $\Delta\Gamma = 1$ ) in Fig. 1.

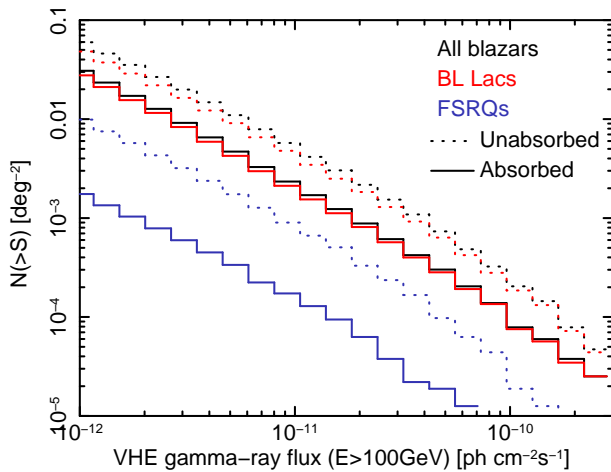
The number counts for the whole blazar sample with and without EBL absorption are shown as black solid and dotted curves respectively. We note that the ratio between the two curves is approximately constant and  $\approx 2$ , which ultimately stems from our intrinsic spectral slopes and redshift distributions.

Fig. 1 also displays the number counts with and without EBL absorption for BL Lacs (red lines), and FSRQs (blue lines). For the case of no absorption (i.e. assuming a fully transparent Universe) BL Lacs are  $\approx 5$  times more abundant than FSRQs, which is a strong selection effect to their very different VHE SEDs. Since EBL absorption affects FSRQs much more than BL Lacs, due to the larger redshifts of the former, an even higher ratio ( $\approx 15$ ) between the two classes is expected when absorption is taken into consideration. Fig. 2 gives a vivid impression of this effect by showing the redshift distribution of BL Lacs and FSRQs before and after taking into account EBL absorption (for the case  $F(> 100 \text{ GeV}) \geq 2.5 \times 10^{-12}$  photon cm<sup>-2</sup> s<sup>-1</sup>). We note that even after the EBL correction some FSRQs are still detectable up to  $z \gtrsim 1.5$  (see below).

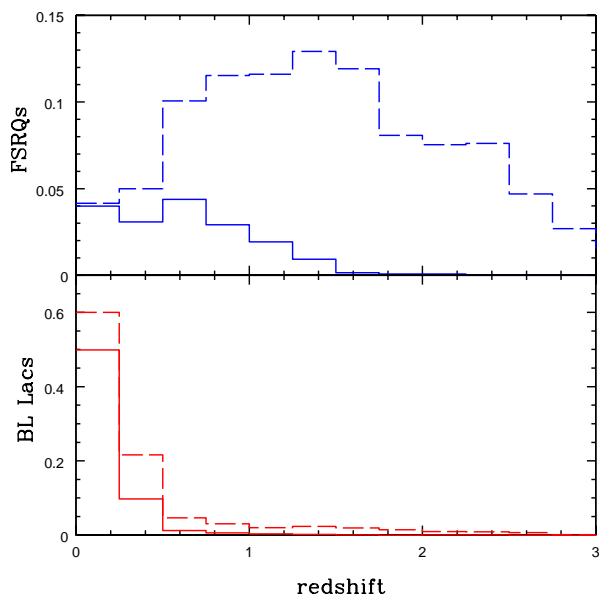
### 3.1 Current IACTs

We start by estimating the number of blazars, which are within reach of present IACTs. This depends on the current

<sup>2</sup> <http://wise2.ipac.caltech.edu/docs/release/allwise/>



**Figure 1.** The predicted integral number counts at  $E \geq 100$  GeV as a function of photon flux with and without EBL absorption (dashed and solid lines respectively) for all blazars (black lines), BL Lacs (red lines), and FSRQs (blue lines) ( $E_{\text{break}} = 100$  GeV and  $\Delta\Gamma = 1$ ).



**Figure 2.** The predicted normalised redshift distributions for FSRQs (top panel) and BL Lacs (lower panel) before (dashed lines) and after (solid lines) applying the EBL absorption correction ( $F(> 100 \text{ GeV}) \geq 2.5 \times 10^{-12} \text{ photon cm}^{-2} \text{ s}^{-1}$ ,  $E_{\text{break}} = 100$  GeV and  $\Delta\Gamma = 1$ ).

typical sensitivity, which is  $F(> 100 \text{ GeV})^3 \approx 7 \times 10^{-12} \text{ pho-}$

<sup>3</sup> This value is based on two arguments: 1. the VHE detection of 1ES 1312–423, which according to HESS Collaboration (2013) is “one of the faintest sources ever detected in the very high energy ( $E > 100$  GeV) extragalactic sky” and, given the fit in the paper, has  $F(> 100 \text{ GeV}) \sim 7 \times 10^{-12} \text{ photon cm}^{-2} \text{ s}^{-1}$ ; 2. Tab. 1 of Şentürk et al. (2013), where a single source has an integral flux  $\sim 1\%$  of the Crab ( $F(> 100 \text{ GeV}) \sim 5 \times 10^{-12} \text{ photon cm}^{-2} \text{ s}^{-1}$ ), while five others are at a level  $\sim 2\%$  of the Crab ( $F(> 100 \text{ GeV}) \sim 10^{-11} \text{ photon cm}^{-2} \text{ s}^{-1}$ ).

ton  $\text{cm}^{-2} \text{ s}^{-1}$  ( $\sim 14 \text{ mC.U.}$ )<sup>4</sup>. We find  $\sim 330$  blazars all-sky without any EBL absorption, which reduce to  $\sim 140$  ( $\sim 230$  in the case of the harder VHE spectrum) once EBL absorption is taken into account. Of these,  $\sim 91\%$  are BL Lacs (7% FSRQs and 2% radio galaxies: see below), a fraction, which is similar to the observed one in TeVCat (94%), the online catalogue for VHE astronomy. Even our predicted fraction of HSP BL Lacs,  $\sim 80\%$ , is close to the observed one (86%). Very recently MAGIC has detected VHE photons from S4 0218+35, an FSRQ at  $z = 0.944$ , during a flaring event (Mirzoyan 2014). This implies a fraction of FSRQs at  $z \geq 0.944 = 25^{+37}_{-21}\%$ , which is also not too far from our prediction of  $\sim 10\%$ . The total number, however, is quite different, with only 54 blazars detected so far. This is easily explained by the fact that TeVCat, although extremely useful, is only a list of TeV sources that is subject to large biases, as there are no all-sky flux-limited TeV catalogues at the moment (with the exception of the Galactic plane: Carrigan et al. 2013). Sources in fact are often pointed by IACTs when found in a high state in other bands. We then predict that  $\gtrsim 100$  blazars are waiting to be detected at  $E > 100$  GeV by current IACTs. For many of these discovery should be relatively easy, as detailed in the next section.

To take into account the fact that the energy threshold of IACTs depends on zenith angle we have estimated the fraction of the sky covered by HESS and Veritas/MAGIC (Fig. 1 of Dubus et al. 2013, where the blind spots corresponds to zenith angles  $> 50^\circ$ ), which turned out to be  $\sim 90\%$ . Our values are therefore overestimated by  $\sim 10\%$ , which is well within the range bracketed by our soft and hard extrapolations.

The latest generation of IACTs, (i.e. MAGIC-II and HESS-II) has a lowered energy threshold reaching a few tens of GeV, with limiting integrated sensitivity of  $\sim 2 \times 10^{-11} \text{ photon cm}^{-2} \text{ s}^{-1}$  at  $E \gtrsim 50$  GeV (Aleksić et al. 2012). Maximum sensitivity, in terms of C.U., is however reached at higher energies: at  $E \gtrsim 300$  GeV the integrated limiting flux is  $\sim 9 \times 10^{-13} \text{ photon cm}^{-2} \text{ s}^{-1}$  (Aleksić et al. 2012). The number of blazar detections expected by our simulations above these limits accounting for EBL absorption is  $\sim 180$  (87% BL Lacs, 11% FSRQs) assuming  $E \gtrsim 50$  GeV, and  $\sim 80$ , (96% BL Lacs, 2% FSRQs) for the case  $E \gtrsim 300$  GeV (these numbers increase by  $\sim 20$  and  $\sim 210\%$  respectively in the case of the harder VHE spectrum). Note that IACTs sensitivities are estimated for a Crab-like spectrum, which is not always representative of blazars. This, combined with the well known large variability of this type of AGN, especially just below 100 GeV where the steep tail of the GeV emission from FSRQs may play a crucial role, makes the above estimates only indicative of average values. IACTs observations simultaneous with optical or X-ray flares may lead to a larger number of detections.

### 3.2 The 1WHSP catalogue

Arsioli et al. (2014) have recently assembled the 1WHSP catalogue, the largest sample of confirmed and candidate HSP blazars. Although technically not a  $\gamma$ -ray catalogue, it

<sup>4</sup> 1 Crab Unit ( $E > 100 \text{ GeV}$ ) =  $5 \times 10^{-10} \text{ photon cm}^{-2} \text{ s}^{-1}$  assuming a spectrum  $\propto E^{-2.6}$ .

represents at present the best way to compensate for the lack of large ( $|b_{\text{II}}| > 20^\circ$ ) sky coverage in the VHE band for blazars. 1WHSP sources have in fact been shown to be strong  $\gamma$ -ray sources:  $\sim 1/3$  of them are confirmed GeV emitters and 35 have already been detected in the TeV band. Arsioli et al. (2014) have defined a “figure of merit” (FoM) on the potential detectability of their sources in the VHE band, defined as the ratio between the synchrotron ( $\nu f_\nu$ ) peak flux of a source and that of the faintest blazar in the 1WHSP sample already detected in the VHE band. Most of the sources with  $\text{FoM} \gtrsim 1.0$  at low and intermediate redshifts ( $\lesssim 0.7$ ) should be detectable by the current IACTs, while the majority of the 1WHSP sample should be within reach of the upcoming CTA. Assuming that the synchrotron peak flux scales as the VHE flux and for a typical sensitivity reachable by current IACTs  $\sim 14$  mC.U. we predict  $\sim 160$  sources above such flux and with  $\nu_{\text{peak}}^S > 10^{15}$  Hz in the 1WHSP catalogue, which reduce to  $\sim 70$  once the effect of the EBL is taken into account. In the case of a harder spectrum these numbers almost double. These values need to be compared with the number of 1WHSP sources with  $\text{FoM} \geq 1.0$ , which is  $\sim 100$ , i.e. larger than expected by our default (soft) VHE extrapolation. The requirements that all sources have an X-ray counterpart and good WISE photometry in at least three bands, furthermore, imply that the 1WHSP catalogue is somewhat incomplete, which might suggest that the intrinsic VHE spectrum of blazars is closer to our harder extrapolation than to the softer one.

### 3.3 The CTA case

We have also made detailed predictions for two distinct hypothetical CTA surveys:  $F(> 100 \text{ GeV}) \geq 2.5 \times 10^{-12}$  photon  $\text{cm}^{-2} \text{s}^{-1}$  (5 mCrab Units [mC.U.]) and a coverage of 10,000 square degrees (Survey 1: larger area, shallower limit) and  $F(> 100 \text{ GeV}) \geq 1.25 \times 10^{-12}$  photon  $\text{cm}^{-2} \text{s}^{-1}$  (2.5 mC.U.) and a coverage of 2,500 square degrees (Survey 2: smaller area, deeper limit). Our results are presented in Tab. 1 – 4 for the unabsorbed and absorbed cases and for the two different VHE extrapolations. Based on our simulations we can draw the following conclusions:

- the total number of blazars expected in Survey 1 is  $\sim 250$  but can be even higher ( $> 400$ ) in the case of a harder spectrum. However, the EBL reduces the sample to  $\sim 110$  objects ( $\sim 50\%$  more for the harder VHE extrapolation), with  $\sim 91\%$  of them being BL Lacs. In Survey 2 (the deeper but smaller one) we expect slightly less than half the number of sources;
- the mean redshift of the sources gets smaller when EBL absorption is applied, which is an obvious consequence of the fact that higher redshifts are more affected. What is less obvious is that the mean redshift of FSRQs is still  $\sim 0.6 - 0.7$ , which means that some of these targets can be detected up to  $z \sim 1.5$ , as shown in Fig. 2 for the Survey 1 case. The very recent VHE detection of S4 0218+35 at  $z = 0.944$  by MAGIC is in full agreement with this prediction;
- the fraction of BL Lacs with redshift increases when the effect of the EBL is taken into account from  $\sim 70 - 80\%$  to  $\gtrsim 90\%$ . This is due to the fact that the sources with no measurable redshift are those with the optical spectra swamped by non-thermal emission, which tend to have a

**Table 1.** Simulation of a CTA survey:  $F(> 100 \text{ GeV}) \geq 2.5 \times 10^{-12}$  ph  $\text{cm}^{-2} \text{s}^{-1}$ , 10,000 sq. deg.,  $E_{\text{break}} = 100 \text{ GeV}$  and  $\Delta\Gamma = 1$ . Mean values correspond to the average of 10 runs.

Source type	Number Unabsorbed	$\langle z \rangle$	Number Absorbed	$\langle z \rangle$
BL Lacs	203.3 (146.8) <sup>a</sup>	0.39	103.7 (91.2) <sup>a</sup>	0.18
FSRQs	40.6	1.45	7.1	0.62
Radio galaxies	3.6	0.05	3.2	0.04
Total	247.5	0.61	114.0	0.21

<sup>a</sup>BL Lacs with measurable redshift

**Table 2.** Simulation of a CTA survey:  $F(> 100 \text{ GeV}) \geq 2.5 \times 10^{-12}$  ph  $\text{cm}^{-2} \text{s}^{-1}$ , 10,000 sq. deg.,  $E_{\text{break}} = 200 \text{ GeV}$  and  $\Delta\Gamma = 0.5$ . Mean values correspond to the average of 10 runs.

Source type	Number Unabsorbed	$\langle z \rangle$	Number Absorbed	$\langle z \rangle$
BL Lacs	356.7 (277.9) <sup>a</sup>	0.41	163.5 (147.5) <sup>a</sup>	0.19
FSRQs	67.6	1.56	8.8	0.63
Radio galaxies	8.0	0.07	6.2	0.06
Total	432.3	0.62	178.5	0.21

<sup>a</sup>BL Lacs with measurable redshift

more powerful jet and therefore are on average at higher intrinsic redshift. Therefore, these are more absorbed than the other BL Lacs;

- as was the case in Paper I and Paper II a small fraction ( $\sim 2 - 5\%$ ) of the simulated blazars are classified as radio galaxies. These are bona-fide blazars misclassified by current classification schemes because their non-thermal radiation is not strong enough to dilute the host galaxy component even in the Ca H&K break region of the optical spectrum (see Paper I and II for more details). Being typically at low redshifts, these sources are not very much affected by the EBL.

The situation at  $E > 1 \text{ TeV}$  is clearly very different. For example, a survey with  $F(> 1 \text{ TeV})^5 \geq 10^{-14}$  photon  $\text{cm}^{-2} \text{s}^{-1}$  and a coverage of 10,000 square degrees should detect only  $\sim 70$  sources taking into account EBL absorption,  $\sim 95\%$  of them being BL Lacs at  $z \lesssim 0.3$  and  $\sim 1$  source being an FSRQ at  $z \sim 0.1$ . For the harder VHE extrapolation the total number increases by  $\sim 50\%$ .

<sup>5</sup> This is the approximate unabsorbed limit for Survey 1.

**Table 3.** Simulation of a CTA survey:  $F(> 100 \text{ GeV}) \geq 1.25 \times 10^{-12}$  ph  $\text{cm}^{-2} \text{s}^{-1}$ , 2,500 sq. deg.,  $E_{\text{break}} = 100 \text{ GeV}$  and  $\Delta\Gamma = 1$ . Mean values correspond to the average of 10 runs.

Source type	Number Unabsorbed	$\langle z \rangle$	Number Absorbed	$\langle z \rangle$
BL Lacs	98.4 (77.6) <sup>a</sup>	0.40	54.9 (49.6) <sup>a</sup>	0.21
FSRQs	20.1	1.52	3.4	0.71
Radio galaxies	2.6	0.07	2.3	0.06
Total	121.1	0.61	66.7	0.24

<sup>a</sup>BL Lacs with measurable redshift

**Table 4.** Simulation of a CTA survey:  $F(> 100 \text{ GeV}) \geq 1.25 \times 10^{-12} \text{ ph cm}^{-2} \text{ s}^{-1}$ ,  $2,500 \text{ sq. deg.}$ ,  $E_{\text{break}} = 200 \text{ GeV}$  and  $\Delta\Gamma = 0.5$ . Mean values correspond to the average of 10 runs.

Source type	Number Unabsorbed	$\langle z \rangle$	Number Absorbed	$\langle z \rangle$
BL Lacs	162.7 (135.5) <sup>a</sup>	0.40	82.5 (76.1) <sup>a</sup>	0.23
FSRQs	31.4	1.61	4.4	0.69
Radio galaxies	6.0	0.10	4.4	0.08
Total	200.1	0.60	91.3	0.24

<sup>a</sup>BL Lacs with measurable redshift

We note that Dubus et al. (2013) have also predicted the number of blazars CTA will detect. Comparing our numbers with those in their Fig. 6 we find that, for example, down to  $E \times F(> 100 \text{ GeV}) \sim 3 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$ , that is,  $F(> 100 \text{ GeV}) \sim 1.9 \times 10^{-12} \text{ photon cm}^{-2} \text{ s}^{-1}$ , we get  $\sim 2 - 3$  (unabsorbed) and  $\sim 3 - 4$  (absorbed) times more blazars, depending on the VHE extrapolation.

This discrepancy is due to the fact that the Dubus et al.'s model is based on EGRET data and it is now known to underpredict the faint Fermi source counts by a factor of two (Y. Inoue, private communication).

Finally, we stress that our simulated blazar sample does not violate the  $\gamma$ -ray background constraint, as measured by *Fermi* (Abdo et al. 2010). We will address this point in detail in a future paper.

## 4 CONCLUSIONS

We have extended our Monte Carlo simulations of the radio through  $\gamma$ -ray emission of blazars within the framework of our proposed blazar simplified view scenario to the VHE band. The blazar SEDs have been extrapolated under some simple assumptions and taking into account EBL absorption. Our predictions are consistent with the number of 1WHSP sources within reach of current IACTs. We have also made detailed predictions for two distinct CTA surveys.

Our main results can be summarised as follows:

- (1) current IACTs should be able to detect  $\gtrsim 100$  more blazars than those already listed in TeVCat. Many of these should be in the 1WHSP catalogue;
- (2) the total number of blazars expected in a CTA survey reaching 5 mC.U. at photon fluxes  $\geq 100 \text{ GeV}$ , covering 10,000 square degrees, and taking into account EBL absorption, is  $\sim 110 - 180$ , depending on the VHE extrapolation. For a survey a factor of two deeper and a factor of four smaller we expect about half the number of sources;
- (3) FSRQs are predicted to make up only a small fraction ( $\sim 5\%$ ) of the sources in the CTA surveys we have simulated. However, since their mean redshift is  $\approx 0.7$ , some of them should be detectable up to  $z \sim 1.5$ , in agreement with the very recent MAGIC detection of S4 0218+35 at  $z = 0.944$ ;
- (4) the redshift of BL Lacs selected at VHE is expected to be easier to determine than for BL Lacs in other bands.

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